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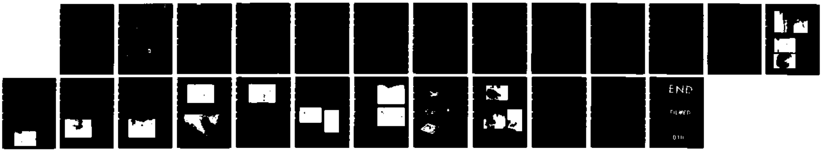

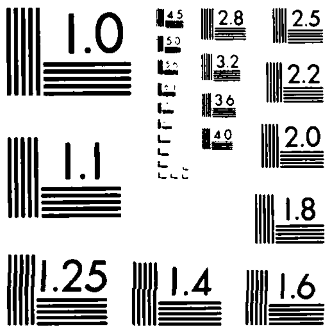

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SACLANTCEN'S USE OF SCUBA DIVING IN OCEANOGRAPHIC AND ACOUSTIC RESEARCH

Federico de STROBEL
Tuncay AKAL
Ole F. HASTRUP

15 DECEMBER 1984

NORTH ATLANTIC TREATY ORGANIZATION

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SACLANTCEN'S USE OF SCUBA DIVING IN OCEANOGRAPHIC AND ACOUSTIC RESEARCH

by
Federico de Strobel
Tuncay Akal
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15 December 1984

This memorandum has been prepared within the SACLANTCEN Underwater Research Division as part of Project 05.

O.F. Hastrup

O.F. HASTRUP
Division Chief

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SACLANTCEN'S USE OF SCUBA DIVING IN OCEANOGRAPHIC AND ACOUSTIC RESEARCH

by

Federico de Strobel, Tuncay Akal, Ole F. Hastrup

ABSTRACT

Over ten years of scientific diving for oceanographic and acoustics research is described. Examples show the need for a scientist to dive even in highly automated activities. Diving operations in oceanographic research have included: deployment of oceanographic buoys and sensors, check-and-recovery operations, installation of bottom-mounted systems, placing fluorescent dye releasers for oceanographic investigations, in-situ calibration of neutrally buoyant floats, and evaluations of low-speed towed bodies. Diving operations in underwater acoustics research have included: visual and stereophotographic investigations and sampling of the sea floor and in-situ measurements of the acoustic characteristics of sediments using geophones and electroacoustic transducers. These operations and techniques are described and some reference is given to organization, safety rules, and operational limits.

INTRODUCTION

Scientific diving at the SACLANT ASW Research Centre started in an informal way in the 1970's. In that period most of the activity was concentrated in the oceanographic field and was based on the personal interests of a few scientists in introducing a new tool for underwater research. The need for scientists to dive and to design new oceanographic instruments that take into consideration their diving capability was demonstrated in several oceanographic operations, such as the following:

- In an early application of diving techniques in 1971 a large spar buoy designed for investigating air/sea interactions was equipped in situ by divers with current meters and a thermistor chain (Fig. 1) that could be recovered and redeployed without removing the large structure of the buoy itself.

- Divers were later used to check the performance and conditions of the thermistor and current meter buoys in the COBLAMED experiments in the Gulf of Lions (Fig. 2) [2]. During these dives, which were made in open water down to a depth of 50 m depth, the angles of tilt of the taut mooring lines were measured, the corrosion and general conditions of the buoy-mounted instruments were investigated, and the current meters were balanced and adjusted horizontally to the best recording position.

- Divers were used to investigate the ocean microstructure off Malta [3]. In this study, dye streaks were carefully injected into the water at required depths by a motionless diver (Fig. 3) and the vertical distribution of the streaks was compared with the vertical temperature profile obtained from a special probe also guided by divers. The comparisons were made by simultaneously filming the two phenomena.

- In an operation conducted in support of the local community, fluorescent dyes were released by divers to monitor the current pattern and the pollution phenomena in the water mass surrounding a proposed sewage outlet in Monasteroli Bay, Cinque Terre, Fig. 4 [4].

Although a number of diving operations had also been carried out for inspection work, bottom investigation, and photographic documentation, only in mid-1974 was the scientific diving activity organized formally in support of the SACLANTCEN research programme. A SACLANTCEN Chief Diving Officer was appointed, rules covering diving operations were promulgated, and scientists with appropriate qualifications were recognized as SACLANTCEN Research Divers.

In general terms the need for scientists to dive and work underwater has been accepted, but this has created the need to classify their activities so that the correct level of safety practices can be applied. Scientific diving has been considered as being somewhere between sports diving and commercial diving, in that, whereas a research diver is primarily a scientist for whom diving is only one tool with which to investigate the ocean, a commercial diver's job is primarily the underwater work itself.

On this basis a code of practice for safe diving has been agreed and promulgated among Italian research centres and SACLANT ASW Research Centre through the Scientific Committee of the CIRSS (Comitato Italiano Studi e Ricerche Subacquee). This code of practice [1], which deals only with scuba diving with no decompression limits, is now in force at SACLANTCEN for those aspects of the Centre's diving operations that are not coverd by the general rules applicable to all scuba diving.

1 DIVING FOR OCEANOGRAPHIC RESEARCH

1.1 General

Oceanographic investigations and data collection at SACLANTCEN are now extremely automated. In oceanographic research, the Centre's research vessel deploys or tows multiparametric sensors to collect and analyze data in real-time on the shipborne computer. Satellite and remote-sensor techniques are also used to provide synoptic pictures of the ocean surface characteristics. Fixed installations, such as surface or subsurface buoy systems, as well as drifting devices, drogues, and neutrally-buoyant floats, are used to collect ocean data over long periods. Ocean bottom characteristics are also investigated by acoustic devices, remote-controlled vehicles, etc.

Even so, it is often still necessary for a scientist to dive in areas where automation costs too much for a specific scientific application, or when instrument data need to be verified by an underwater investigation or when, as often happens, new instruments have to be tested at the design and testing stage. Among SACLANTCEN's oceanographic activities there have been several areas, mainly in oceanographic instrumentation, in which scientific diving has played an active role in the design, installation, or calibration stage.

1.2 Oceanographic Buoys

Most of SACLANTCEN's deployments and recoveries of surface or subsurface buoys, especially in shallow water, have been simplified and safely performed by using diving assistance. In particular, buoys have been located by diver-operated acoustic locators, divers have inspected and checked buoys for corrosion, and the conditions of buoys have been photographically documented by divers.

The SACLANTCEN-designed digital thermistor chain (Fig. 5a) is another good example of the application of diving techniques in the development of oceanographic buoys. This device, which carries a set of 30 temperature probes from which information is digitally stored on a self-recording data-acquisition system, can be installed by divers on a surface or subsurface mooring system to provide long time series of the thermal variability of the ocean. The basic characteristics of the buoy allow the divers to check the working conditions of the unit and to recover and replace the data-acquisition unit and the battery package as often as requested, thereby extending the buoy's autonomy and the retrievability of the recorded data with a minimum interruption of measurements. Any other solution would call for the recovery of the whole system, including the buoy and the mooring line, resulting in a longer interruption of measurements and with the important disadvantage that it would probably be impossible to redeploy the buoy in exactly the same position as previously.

An important factor to be considered for a diving operation of such a type was the problem of divers making underwater electrical connections (Fig. 5b). Special design criteria to take account of electrical hazards comprised:

a) the choice of reliable underwater-pluggable electrical connectors,

b) the use of external, diver-operated power switches,

c) the use of low power and voltage,

d) care in handling electronic components during and after a diving operation in view of possible changes in the impedance of human skin.

1.3 Towed Bodies

Since 1974 SACLANTCEN has developed oscillating towed CTD (conductivity, temperature, depth) devices for contouring upper ocean variability so as to relate the temperatures measured near the surface with those measured at

the surface by satellite sensors. The recent version [5] shown in Fig. 6a, consists essentially of a sensor-carrying fish that is automatically oscillated up and down a weighted main cable streamed behind the ship. The fish is oscillated vertically by paying in and out an electromechanical cable from an electronically controlled winch on the ship's stern. The fish is finned and pivoted to responds to these movements.

Design verification and in situ adjustment of this sensor-carrying fish required several underwater observations (Fig. 6b) of its towing conditions. Because such observations are difficult to achieve in a towing tank because of depth limitations they were made by towing and oscillating the fish in about 25 m of water within sight of a diver, or by having the diver towed at a safe depth and distance by a separate rope attached to the main weight or cable.

1.4 Drifting Floats for Measuring Mid and Deep Water Circulation

The deep-sea circulation of the Alboran basin has been investigated by SACLANTCEN recoverable acoustic Swallow floats (Fig. 7a). These consist of a 1.5 kHz low-frequency acoustic pinger with an extremely accurate timing sequence and housed in a glass sphere that can be preballasted so as to be positioned at any depth in equilibrium with the surrounding water mass [6,7]. The transmitted acoustic signals can be tracked from the ship or from permanently moored listening stations. In this way the floats' trajectories can be plotted to show the circulation of the water in the horizontal plane.

Advanced laboratory techniques are used to calibrate the balance of the float at the surface and to compute the thermal and pressure compressibility with depth. But the basic information on the non-linear compressibility of the unit at low pressure (air bubbles, rubber components, etc.) has been obtained by diving techniques. The floats were accurately balanced (within 1 g) at different water depths in the upper layer by divers (Fig. 7b), while the density of the surrounding water mass was monitored by CTD measurements. The operation had to be conducted in drifting and motionless conditions by a team of divers in the same perfect equilibrium with the water density as were the floats.

1.5 Bottom-mounted Structures

Some oceanographic or acoustic projects have required the deployment on the sea bottom of structures carrying dedicated sensors (Fig. 8). The choice of ideal spots for such investigations, which is fundamentally a scientific activity, has been determined from bottom surveys made by diving scientist.

After positioning the necessary structure, divers have inspected the condition of the sensors and have sometimes modified their orientation. They have also checked the correct laying of the electromechanical cable connecting the sensor package to the supporting vessel or the shore laboratory.

Poor underwater visibility has sometimes called for a cable-less communication system so as to conform with the standard safety-diving rules for that special situation [1].

2 DIVING FOR UNDERWATER ACOUSTICS RESEARCH

2.1 General

Acoustic energy interacting with the sea-floor is reflected by the bottom and sub-bottom layers and is scattered by the bottom surface. The physical properties of the bottom and sub-bottom layers affect the reflection processes and the form of the bottom affects the scattering processes. Thus the bottom and sub-bottom characteristics of the sea-floor are essential parameters in underwater acoustic research.

Different techniques are used to measure these parameters [8]; one of these is for divers to make direct investigations. At SACLANTCEN, diving is used to conduct controlled experiments to determine the composition, structure, and distribution of the bottom materials and to obtain undisturbed in situ measurements of acoustical and geotechnical parameters, as described below.

2.2 Visual Investigation of the Ocean Bottom

Acoustic studies often require the identification of areas in which a specific bottom type is dominant. One of the problems in selecting such characteristic areas is to ensure that the samples taken are representative and that the bottom type does not vary significantly within the area of interest. For this reason divers have been used to visually investigate the extent of the area selected. Figure 9a shows typical areas chosen in this way in the vicinity of La Spezia, each characterized by different bottom types.

2.3 Sampling for Laboratory Analysis of the Ocean Bottom

When an area has been selected for acoustic studies it is very useful for a diving scientist to observe and sample sea-floor material. He can ensure that representative and almost undisturbed samples are obtained for detailed laboratory analyses. Figure 9b shows the diver-operated bottom sampler in use. Figure 9c shows some of the results of laboratory analyses [9] of the samples taken by divers within selected areas.

Other bottom-sampling devices developed at SACLANTCEN have also been improved by divers.

2.4 In-situ Acoustic Measurements of the Ocean Bottom

However, the transfer of samples from the bottom to the surface by divers can itself disturb the characteristics of the parameters. Other techniques are therefore being developed to make in situ measurements of some of the acoustic properties of the bottom. Figure 10 illustrates a technique used at SACLANTCEN to measure the compressional and shear-wave velocities and their attenuation characteristics. This basically consists of recording the responses of three in-line bottom-mounted geophone stations to signals generated by a sledgehammer. As shown in Figs. 10a and b, the diver hits a cast-iron block that has been partially buried in the sediments so as to ensure good energy coupling between the vertical and transverse signals. The resulting signals (Fig. 10c) received by the reference hydrophone and

the geophone array are then transmitted through a multiconductor cable to the research vessel where they are recorded and preliminary analysis conducted.

2.5 Photography of the Ocean Bottom

The application of photogrammetric techniques to stereo-photographs of the sea floor is a common method of obtaining quantitative data on small-scale roughness [10,11]. For measuring large-scale bottom features, the limits on photography imposed by poor visibility and camera aperture size can be reduced by the use of divers. By using a grid, photogrammetric mapping of large features can be carried out accurately by divers.

Two systems have been used at SACLANTCEN for underwater stereo-photography. One (Fig. 11a) is a general system (E.G. and G. Bethnos) with manual or remote-control options. The other (Fig. 11b) is a hand-held camera (Photo-sea 2000) that can be easily operated by divers. Both systems provide stereo-photographs from which quantitive data on small-scale sea-floor roughness can be obtained.

Figure 11c shows a contour map and a 3-dimensional relief map of an ocean bottom obtained by the use of stereo-photography and photogrammetric mapping techniques. The figure also shows the two-dimensional power spectrum and autocorrelation function of the sea floor obtained from the same data.

2.6 Other Applications

a) Diving scientists have also played an important role in the development of many of the sampling devices and instruments deployed on the bottom. Figure 12 shows an ocean-bottom seismometer (OBS) that has been successfully used for the study of seismic propagation in the ocean bottom [12]. In developing and deploying this system, diving scientists determined the best ground coupling and deployment techniques for isolating the system from sea-surface motions, currents, etc.

b) Observations and monitoring by diving scientists during the collection of data has been found to provide a very good background for their later interpretation of the data (Figs. 13a and 13b).

CONCLUSIONS

The successful underwater scientist is one who can design his experiment to overcome the limitations of working in the sea. Most of the methods used to obtain data from the sea-floor and below are indirect measurements in which the water-mass normally separates the scientist from the environment he is studying.

Although conventional surveying and sampling techniques are essential, there are many types of observations and operations that can be carried out only by divers. Even though diving operations are limited by depth, many parameters measured during well-controlled experiments by divers can be extrapolated to greater depths. SACLANTCEN will therefore continue to use diving as a tool in its research programme.

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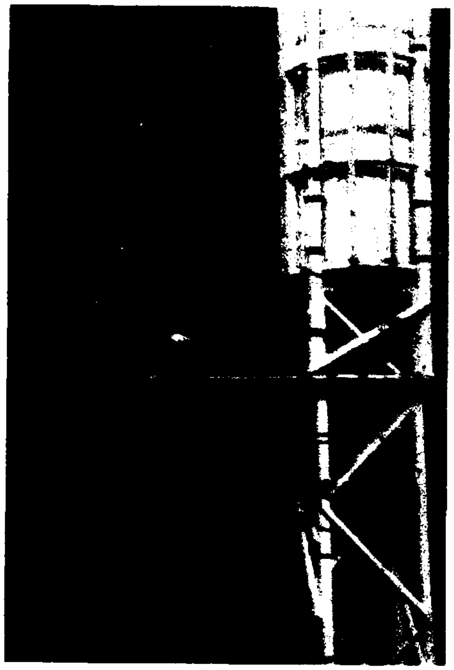


FIG. 1
METEO-OCEANOGRAPHIC SPAR BUOY BEING EQUIPPED WITH SENSORS BY DIVERS

FIG. 2
DIVERS CHECKING CORROSION ON A TAUT-MOORED OCEANOGRAPHIC SURFACE BUOY

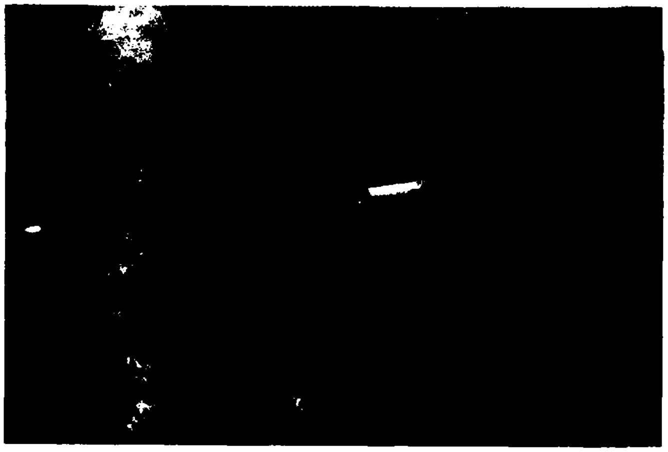
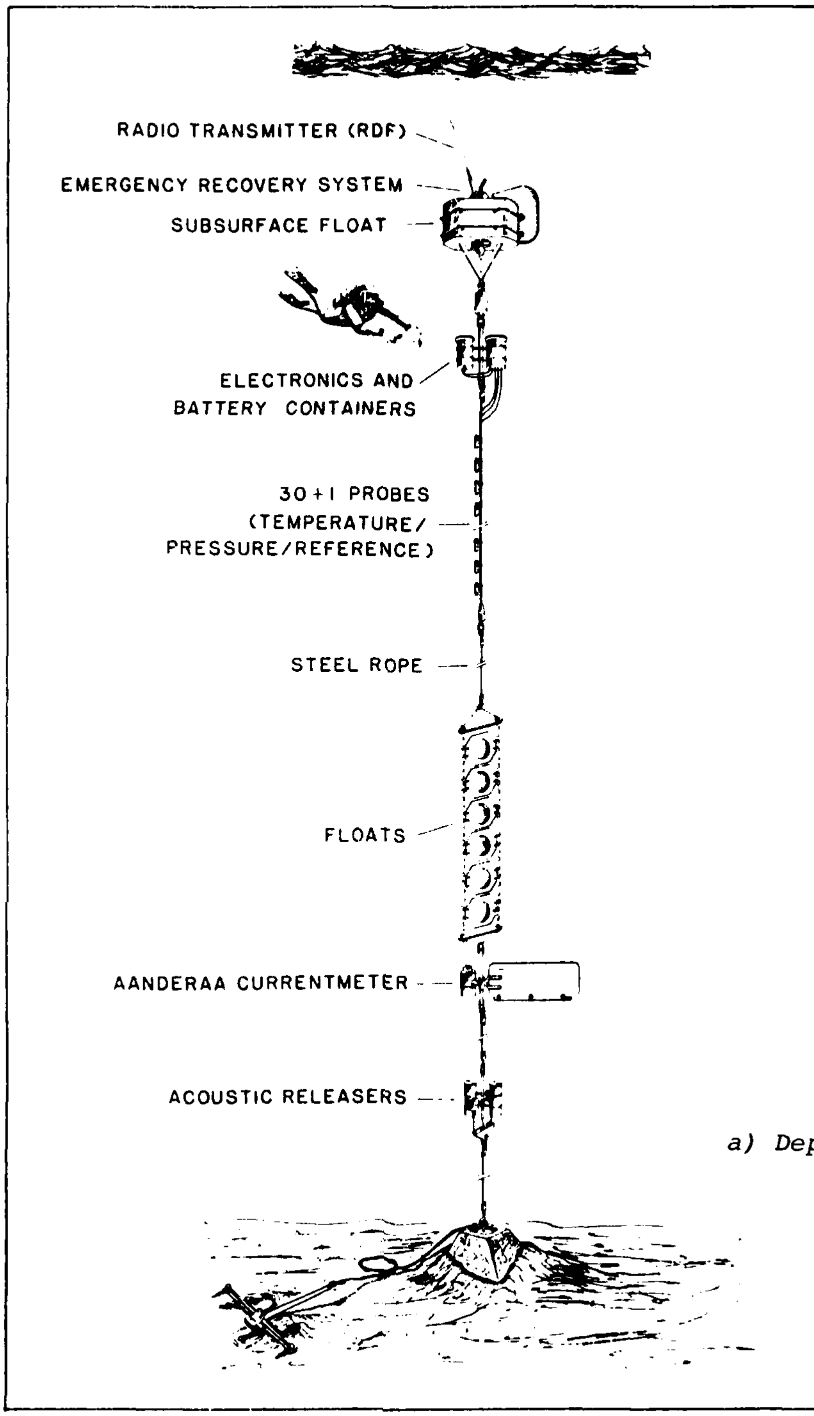


FIG. 3
DIVER RELEASING FLUORESCENT DYE STREAKS DURING AN INVESTIGATION OF OCEANIC MICROSTRUCTURE

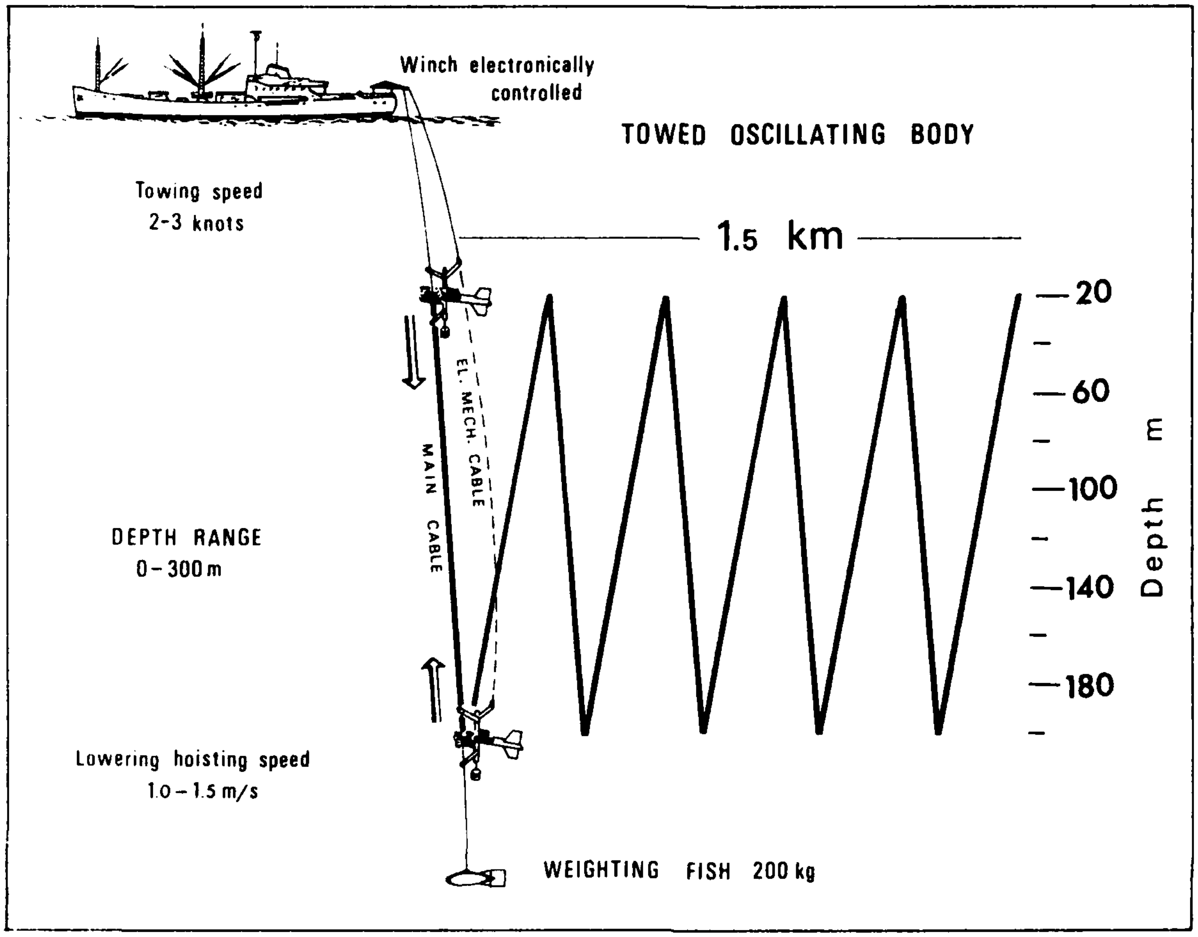
FIG. 4
DIVER RELEASING DYE TO MONITOR CURRENT PATTERNS AND POLLUTION PHENOMENA



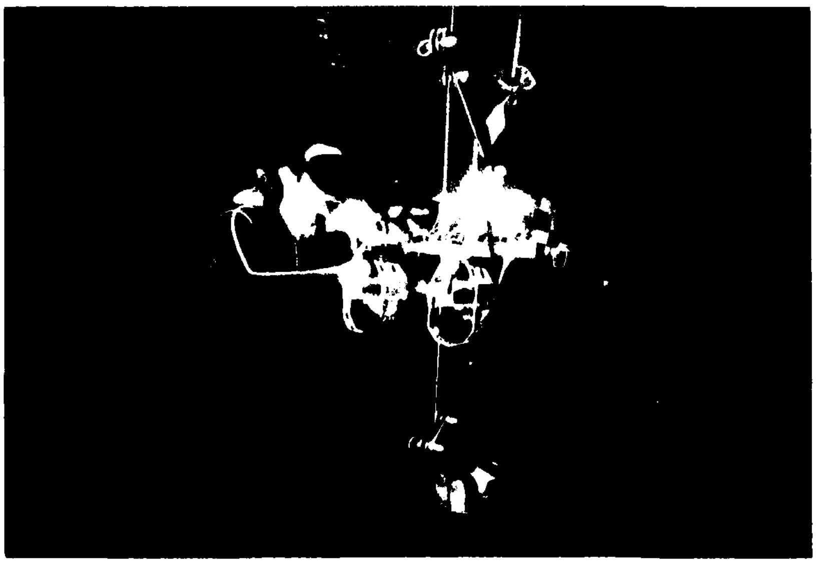
a) Deployment.

b) Divers replacing the data-acquisition package.

FIG. 5 SUBSURFACE THERMISTOR BUOY SYSTEM

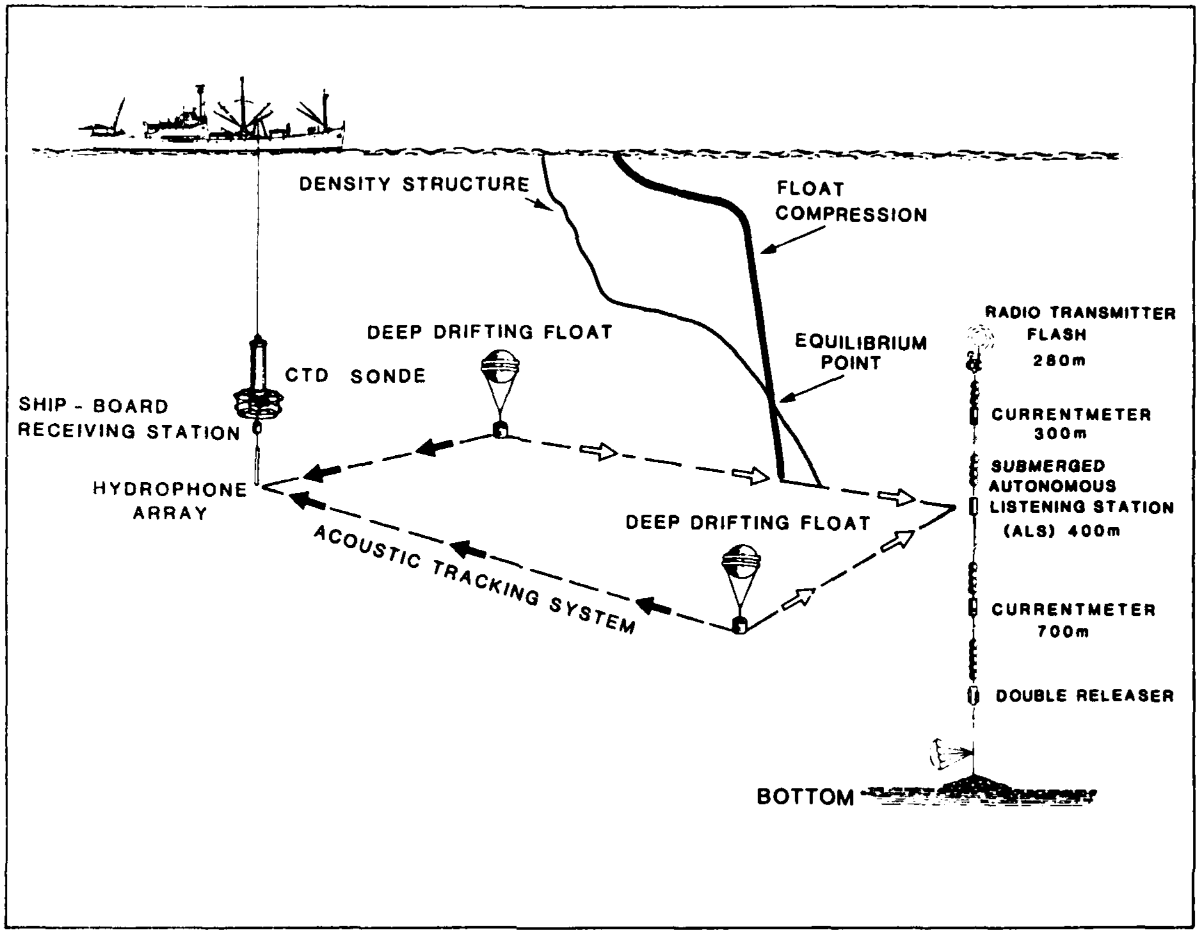


a) Operation.



b) Diver adjusting the sensor package in situ.

FIG. 6
TOWED OSCILLATING BODY FOR CONTOURING UPPER-OCEAN VARIABILITY



a) Deployment and operation.

b) Diver obtaining information on the non-linear compressibility of a float.

FIG. 7
DRIFTING, NEUTRALLY-BUOYANT, ACOUSTIC FLOATS FOR MONITORING THE HORIZONTAL CIRCULATION OF THE DEEP OCEAN

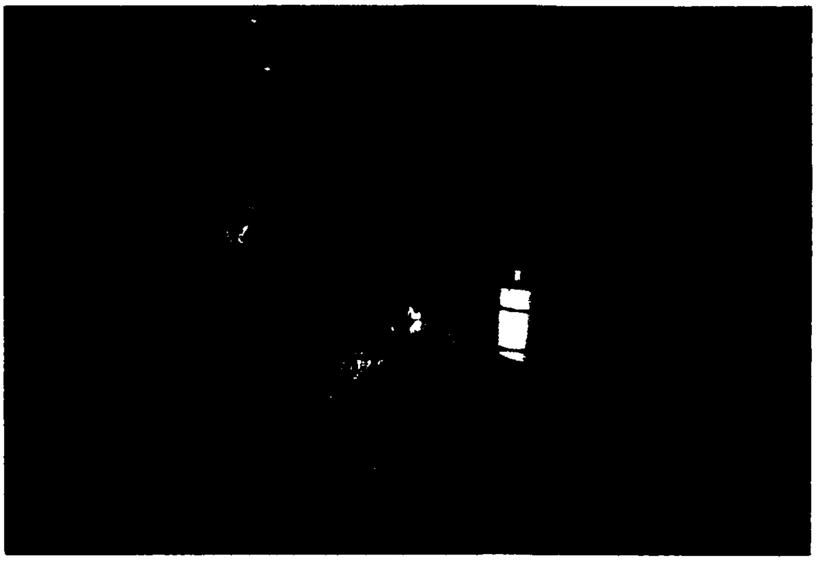


FIG. 8
DIVER DEPLOYING A BOTTOM-MOUNTED STRUCTURE CARRYING DEDICATED SENSORS

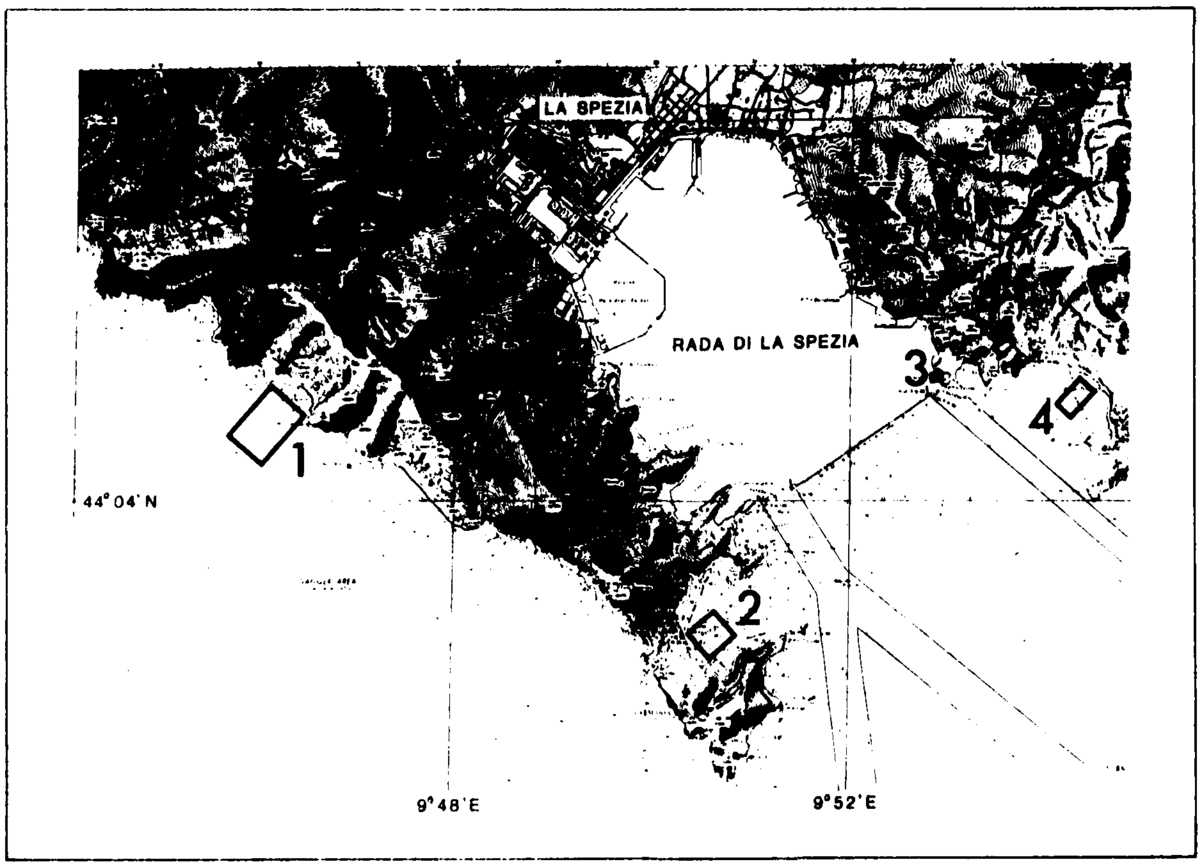
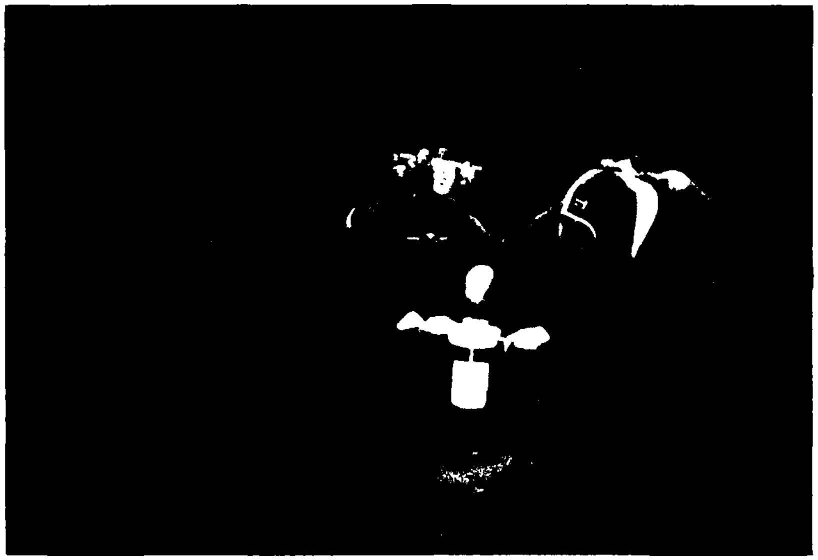
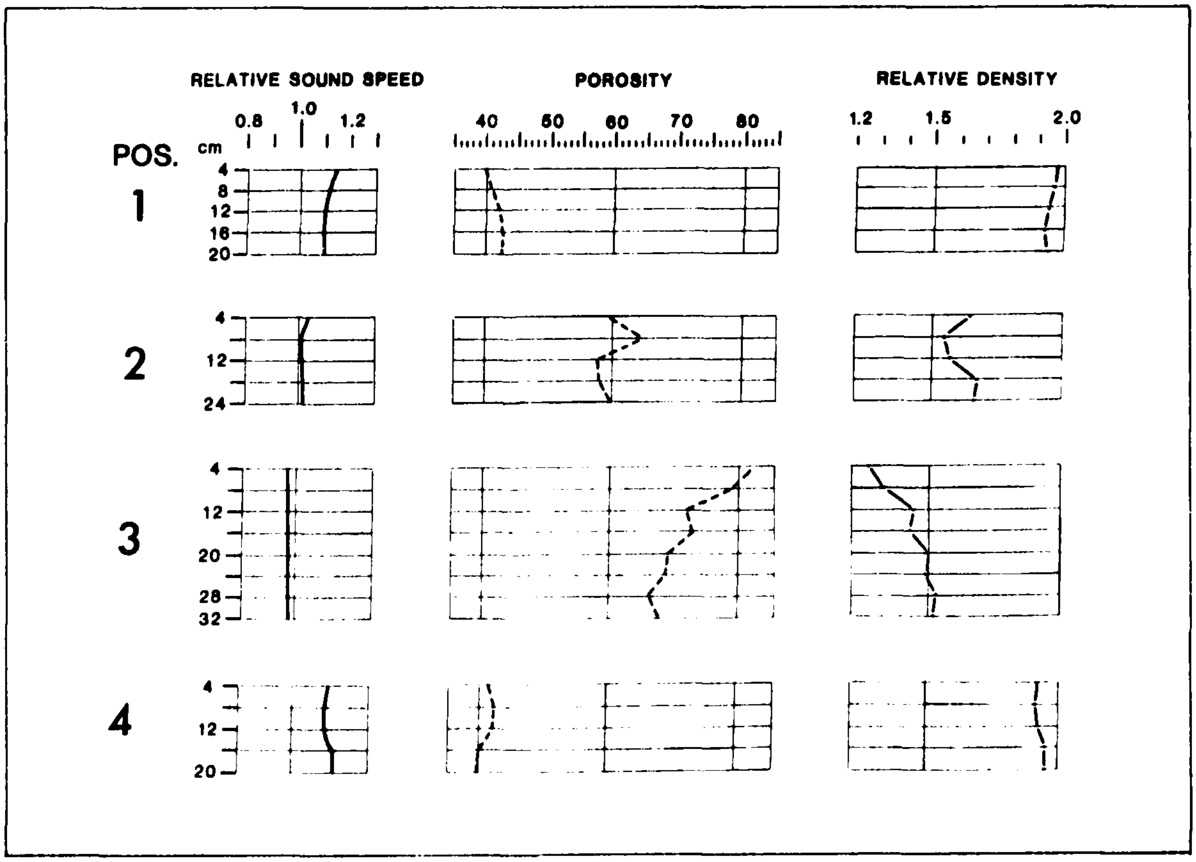


FIG. 9 BOTTOM SAMPLING FOR ACOUSTIC EXPERIMENTS
a) Areas with characteristic bottoms chosen by divers for acoustic experiments in the La Spezia area.

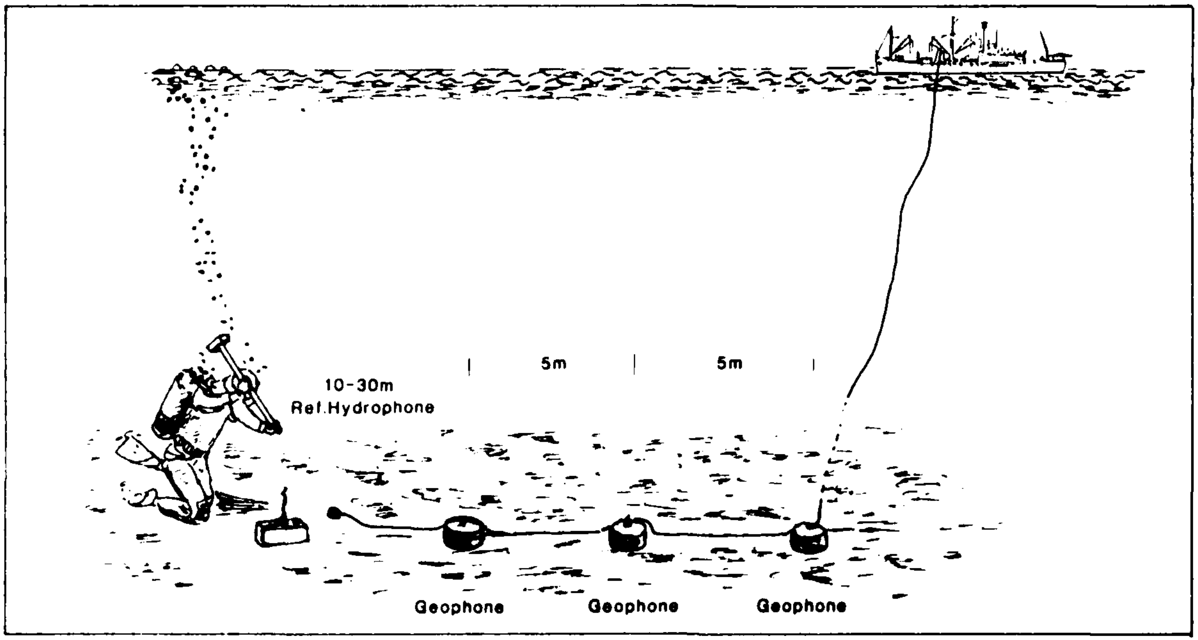


b) Diver sampling the sea bottom.

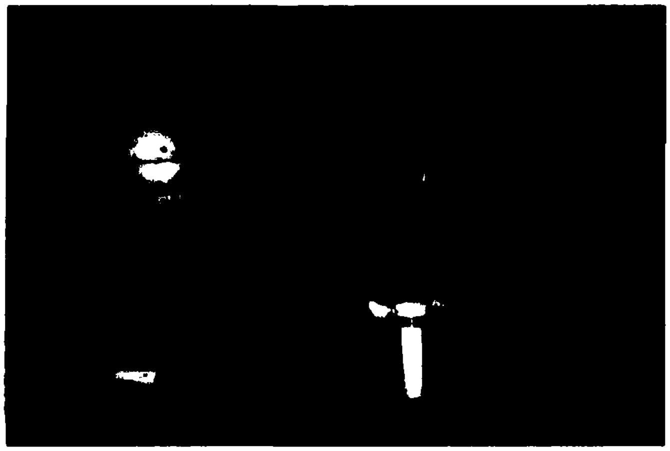


c) Laboratory analyses of some bottom samples.

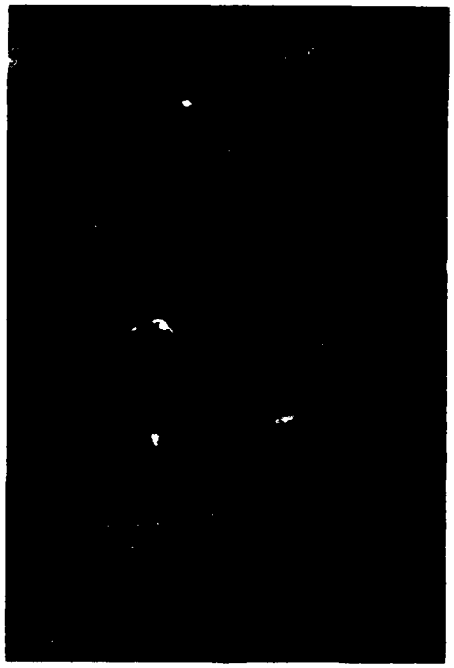
FIG. 9 BOTTOM SAMPLING FOR ACOUSTIC EXPERIMENTS



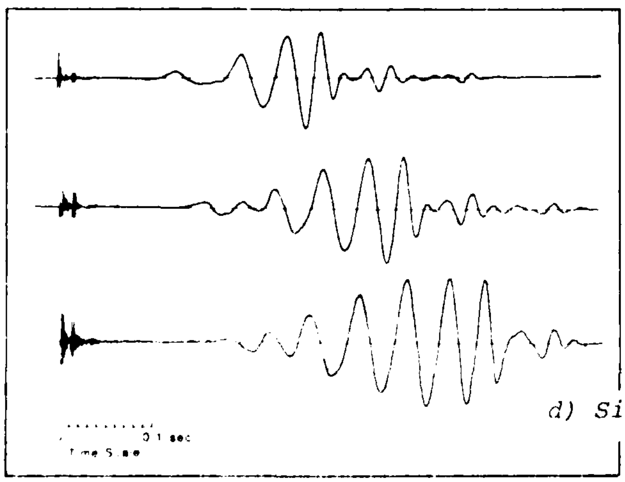
a) Method: Diver hits partially buried cast-iron block with sledgehammer; signals received by reference hydrophone and geophone array are transmitted to ship for analysis.



c) Seismic signals were also generated by a spear gun hitting an iron block (seen behind the diver operating the bottom sampler).

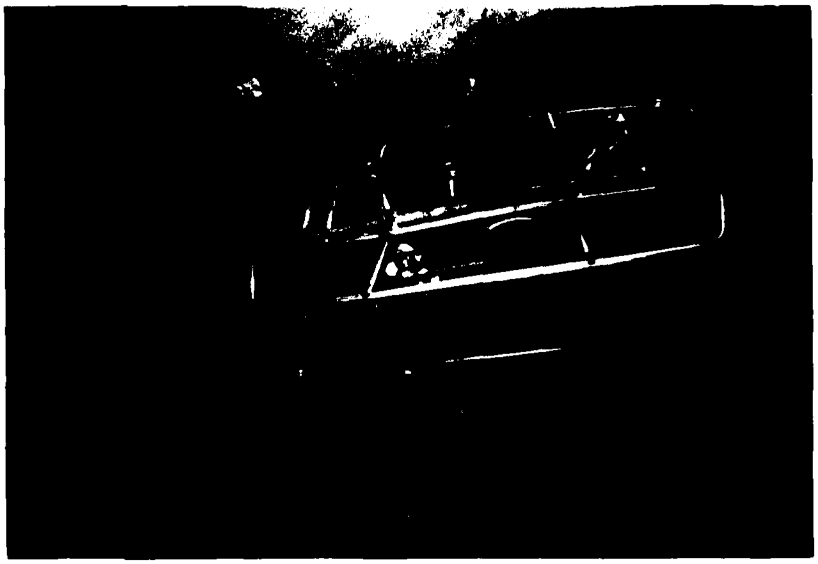


b) Diver striking block; note geophone in foreground.



d) Signals received from three geophones.

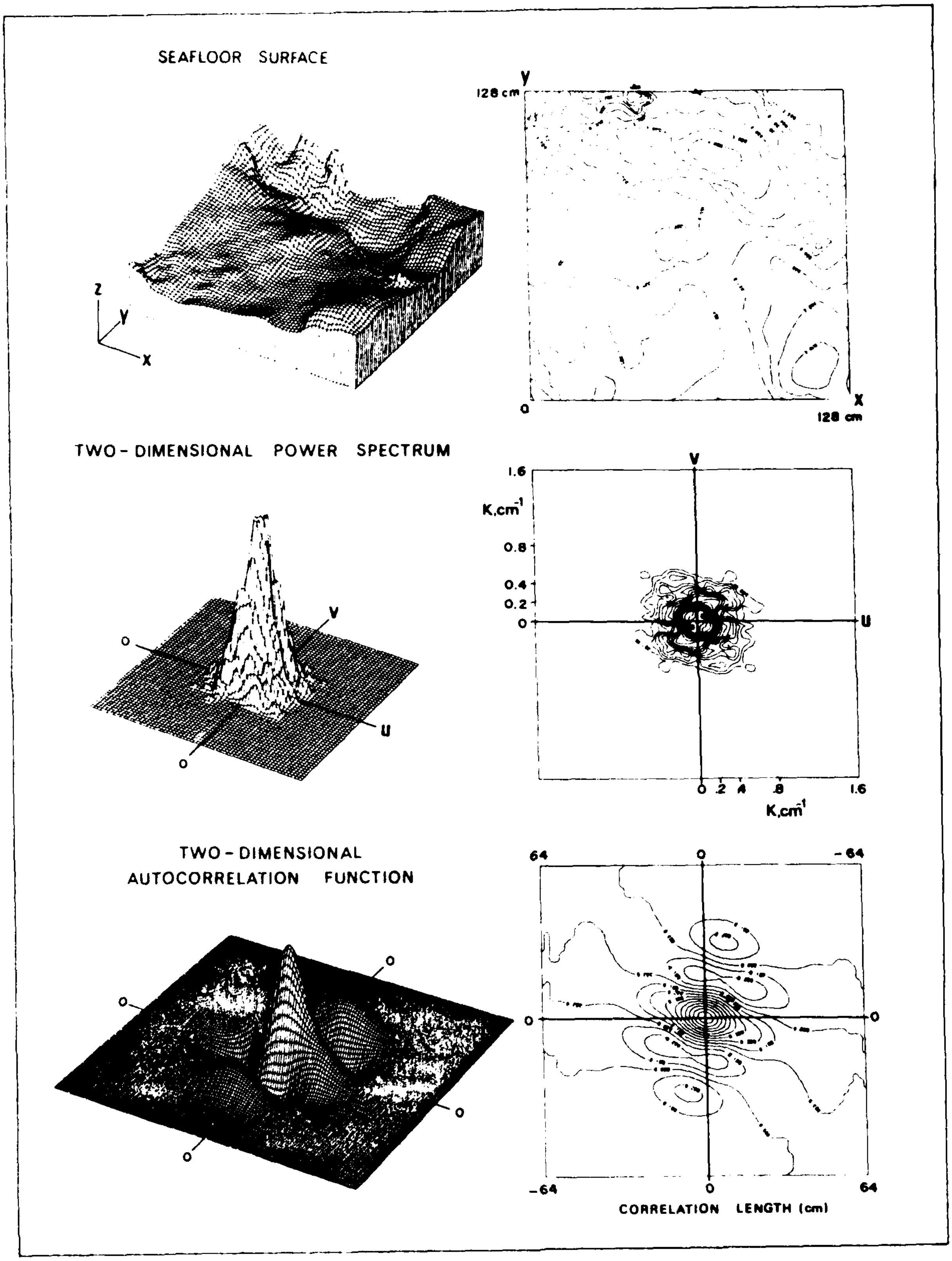
FIG. 10 IN SITU MEASUREMENTS OF THE ACOUSTIC PARAMETERS OF THE OCEAN BOTTOM



a) E.G. & G (Benthos) system in use by diver.

b) Photo-sea 2000 system in use by diver.

FIG. 11
STEREOPHOTOGRAPHY AND PHOTOGRAMMETRY OF THE OCEAN BOTTOM



c) *Results of stereophotography and photogrammatic techniques.*

FIG. 11 STEREOPHOTOGRAPHY AND PHOTOGRAMMETRY OF THE OCEAN BOTTOM

FIG. 12
OCEAN-BOTTOM SEISMOMETER DEVELOPED AND DEPLOYED BY USING DIVERS

a) Observations and monitoring during the data collection provides a good background during the interpretation

b) Checking and calibrating the sink rate of a dummy SUS-95 charge (Sound Underwater Source).

FIG. 13
DIVERS MONITORING DATA COLLECTION

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OCEANOGRAPHIC DIVING
RESEARCH DIVING
SAFETY
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